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Risk Factors for Injury Associated with Low, Moderate, and High Mileage Road Marching in a U.S. Army Infantry Brigade

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14. ABSTRACT Road marching is an important physical training activity that prepares soldiers for this common occupational task. Continued exploration of risk factors for road marching-related injuries is needed. **Purpose**: To evaluate the association between modifiable characteristics of physical training and individual fitness with road marching-related injury risk. **Methods**: Injuries in the previous 6 months were identified by survey from 831 U.S Army infantry soldiers. Road marching-related injuries were reported as those attributed to road marching on foot for specified distances while carrying equipment. Frequencies, means, and relative risks (RR) of injury for road marching-related injury with 95% confidence intervals (CI) were calculated. Adjusted odds ratios (OR) and 95%CI were calculated for leading risk factors using multivariable logistic regression. **Results**: Half (50%) of reported injuries were attributed to road marching or running. When miles of exposure were considered, injury risk during road marching was higher than during running ($RR_{road\ marching/running}$=1.81, 95%CI:1.38-2.37). A higher product of marching distance and weight worn (pound-miles per month) resulted in greater injury risk ($RR_{\geq 1473\ pound\text{-}miles/<1472}$= 92, 95%CI:1.49-2.46). Road marching-related injuries were associated with carrying a load ≥26% of one's body weight ($OR_{\geq 26\%/1\text{-}20\%}$ =2.09, 95% CI:1.08-4.05), having high occupational lifting demands ($OR_{50\text{-}100+lbs/25\text{-}50lbs}$ =3.43, 95% CI:1.50-7.85), road marching ≥5 times per month ($OR_{\geq 5\ times/4\ times}$ =2.11, 95% CI:1.14-3.91), and running <4 miles per week during personal physical training ($OR_{0/\geq 10\ miles/week}$ =3.56, 95% CI:1.49-8.54, $OR_{1\text{-}4/\geq 10\ miles/week}$ =4.14, 95% CI:1.85-9.25). A high number of pound-miles completed during road marching was also significantly associated with injury, indicating that the combined effects of distance and weight carried increase injury risk ($OR_{\geq 1473/1\text{-}750\ pound\text{-}miles/month}$ = 1.99, 95% CI:1.05-3.79). **Conclusion**: Ideally, attempts should be made to decrease the percentage of body weight carried and distances marched to reduce road marching-related injuries. Since this is not always operationally feasible, reducing the cumulative overloading from both physical training and occupational tasks may help prevent injury.

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1 Summary

1.1 Purpose

The purposes of this investigation were to assess injury incidence by road marching and running distance, compare differences in physical training with varied road marching distances per month, and determine factors associated with risk of road marching-related injuries for low, moderate, and high mileage road marching participants.

1.2 Methods

This was a secondary analysis of data received as part of an initiative to identify injury risk factors in two infantry battalions. The following data were collected: demographics, performance on the most recent Army Physical Fitness Test (APFT), activities related to unit and personal physical training (PT) in the previous 6 months, road marching participation in the previous 6 months, occupational demands for lifting and aerobic activities, current tobacco use, and injuries occurring in the previous 6 months. Descriptive statistics for the subset of injuries occurring during road marching were produced, and potential risk factors for road marching injury were analyzed using univariate and multivariable logistic regression. Review and approval for this project was obtained from the U.S. Army Public Health Center (APHC) Public Health Review Board (PHRB).

1.3 Results

The questionnaire had 831 respondents, 310 of whom (37 percent) reported a total of 412 injuries. Road marching was the reported activity associated with 23 percent (n=96 out of 412) of injuries, second only to running for physical training at 27 percent (n=113 out of 412). About half of the road marching injuries (n=49) resulted in injuries with temporary duty restrictions (21 percent of reported restrictions) and 1,795 limited duty days (20 percent of reported limited duty days) during the 6 months prior to survey administration.

Most respondents (89 percent, n=736) reported participation in road marching with their unit during the 6 months prior to survey administration. Among those who participated, the average frequency reported was five times per month and the average distance reported was 7.4 miles per session. The average weight carried was reported to be 44 pounds (20 kilograms) per session. When accounting for miles of exposure, road marching was associated with higher rates of injury (Relative Risk (RR) =1.81, 95 percent Confidence Interval (CI) 1.38-2.37) and injuries resulting in limited duty (RR=1.41, 95 percent CI 0.98-2.02) when compared to running.

Among all respondents who participated in road marching, those who were injured reported carrying a significantly heavier load, participating in less distance running, and conducting more resistance training sessions, compared to those who were uninjured ($p \leq 0.05$). As average road marching distance increased, so did the average load carried, running frequency and mileage, and the frequency and duration of participation in resistance training. Those respondents injured during road marching carried more weight on average than their counterparts who were not injured during road marching. Soldiers who marched the greatest distance (≥33 miles) and experienced a road

marching-related injury reported a greater frequency of resistance training and more time spent per week participating in resistance training.

The injured body areas frequently reported during road marching were back (26 percent), knee (23 percent), and ankle (18 percent). The most predominant type of injury was sprains/strains (46 percent). The most commonly cited mechanisms of injury during road marching were overuse/repetitive activity (60 percent), single session overexertion/over-extension (19 percent), and falling (6 percent).

When multivariate regression analysis was conducted, the following factors were associated with road marching injuries among all road marching participants: age ≥35, having a job that required heavy lifting, road marching ≥5 times per month, running <5 miles per week for personal PT, and carrying >25 percent of one's body weight when road marching. The number of pound-miles completed per month (reported road marching weight multiplied by distance) was also significantly associated with injury.

For those individuals reporting the lowest amount of road marching (≤19 miles per month), holding a senior enlisted rank or a being a current smokeless tobacco user were associated with almost four times the odds of injury compared to lower enlisted respondents and those who did not report smokeless tobacco use, respectively. For those who reported road marching an average of 20–32 miles per month, two factors were associated with road marching injuries: officer rank and not participating in running for personal PT. For those who reported road marching the greatest distances each month (≥33 miles), having a job that required heavy lifting, participating in running during personal PT but for <4 miles per week, and participating in resistance training for >30 minutes per session during personal PT were associated with road marching-related injuries. Carrying >26 percent of one's body weight during road marching was marginally associated with road marching-related injuries. Those who reported a higher product of weight worn and distance marched (≥1473 pound-miles) were at a greater risk of injury compared to those who reported less.

1.4 Conclusions and Recommendations

Among this population of infantry Soldiers, high amounts of physical activity were the predominant risk factors for the occurrence of a road marching injury. Participation in other weight bearing activities like occupational lifting and resistance training was significantly associated with injury, indicating that the cumulative effects of overloading with these activities is hazardous.

Physical training programs should incorporate a variety of activities that are balanced in terms of frequency, duration, and intensity in order to enhance physical endurance and reduce injury risk. Furthermore, those who participated in more road marching were more likely to be injured if the carried load was heavier than 25 percent of their body weight. Those with the highest combined reported road marching distance and weight (highest pound-miles per month) were also at a significantly increased risk of injury. Therefore, the distance marched and the weight of carried loads should be reduced to this level and carried as efficiently as possible. However, as heavy loads are often required for long distances during deployment, preventing cumulative overloading from both physical training and occupational tasks may be the most practical approach to reduce road marching-related injuries.

2 References

See Appendix A for a listing of references used within this report.

3 Authority

The authority for APHC involvement in the evaluation of the program is Army Regulation (AR) 40-5, paragraph 2-19a (Department of the Army (DA) 2007), which tasks the APHC to provide "support of Army preventive medicine activities through consultations, program evaluations in the areas of disease and injury prevention and control, and health surveillance and epidemiology."

4 Background

Military missions require Service members to maintain a high level of physical fitness, such that they are able to perform rigorous military tasks in various environments and conditions. Service members achieve these high levels of fitness through both mandatory physical training with their unit and optional physical training during personal time (Department of the Army 2012). Road marching (also referred to as foot marching, ruck marching, and load carriage) is often a required part of training in the U.S. Army (Army Public Health Center (Provisional) (APHC(P) 2016). Road marching is an endurance activity that involves moving a specific distance while carrying weight in a rucksack or military backpack, in order to physically condition Soldiers, acclimate them to carrying a heavy load, and enhance combat readiness during overseas missions (Department of the Army 1990; North Atlantic Treaty Organization Research and Technology Organization (NATO-RTO) 2009). Carrying heavy loads that include equipment, weapons, ammunition, and other supplies often required in combat situations. U.S. Army Soldiers in recent overseas operations have worn up to 60 kilograms (130 pounds) of equipment (Knapik et al., 2004; NATO-RTO, 2009).

In general, aerobic endurance attained as a result of physical training has been shown to be protective against injury (Grier et al. 2017; Knapik 2014). However, previous studies and reviews of military injuries have identified sports and exercise (e.g., running, weight training, basketball, and football) as activities that are commonly associated with injury (Grier et al. 2017; Hauret et al. 2015; Jones and Hauschild 2015). Likewise, road marching with a load has been associated with a variety of neuromusculoskeletal injuries in military populations (Andersen et al. 2016; APHC(P) 2016), especially to the lower extremities and back (Knapik and Reynolds 2015; Konitzer et al. 2008; Orr et al. 2016b; Orr et al. 2015; Roy et al. 2012b; and Roy et al. 2013). Injuries during road marching are believed to be a result of increased energy expenditure (Pandolf et al. 1976), excess stress on the trunk (Knapik and Reynolds 2015; Yang et al. 2015), and modified gait patterns (Knapik et al. 2004; Taylor et al. 2016; Yang et al. 2015. Figure 1 depicts a Soldier carrying a rucksack and describes potential road marching-related injuries.

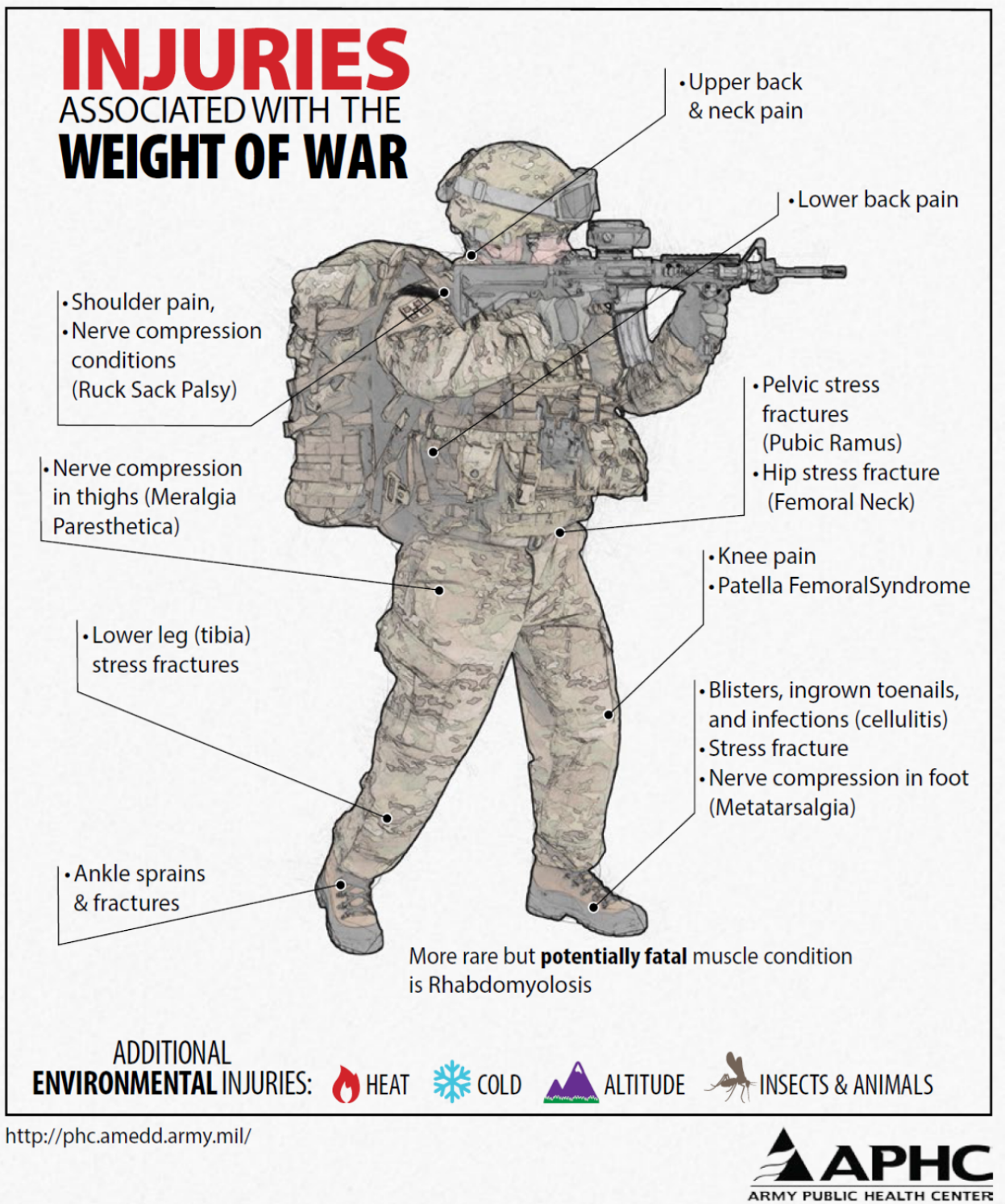

Figure 1. Potential Injuries Due to Road Marching (created by Army Public Health Center)

Previous studies have considered injury incidence, injury types, injured body areas, and injury risk factors during military road marching. The purposes of this investigation were to compare injury incidence for road marching and running participants, assess differences in physical training with varied road marching distances per month, and determine factors associated with the risk of road marching-related injuries for low, moderate, and high mileage road marching participants.

5 Methods

5.1 Survey Design and Administration

An electronic survey was administered to members of two non-deployed U.S. Army infantry battalions using the Verint® Enterprise Feedback Management system, from November 2014 to January 2015. The following data were collected: (1) demographics, performance on the most recent APFT, (2) activities related to unit and personal PT in the previous 6 months, (3) road marching participation in the previous 6 months, (4) occupational demands for lifting and aerobic activities, (5) current tobacco use, and (6) injuries occurring in the previous 6 months. Injury was defined on the survey as a physical injury caused either by a single incident or accident or by overuse of a body area that resulted in physical damage to the body and limited physical abilities. Detailed questions were asked about the two most physically limiting injuries occurring in the 6 months prior to survey administration. Survey questions were designed in collaboration with members from the medical department at the brigade's installation.

5.2 Human Protections Review

The survey and associated investigation were approved by the APHC (Prov), PHRB as public health practice.

5.3 Data Analysis

This was a secondary analysis of data received as part of an initiative to identify injury risk factors in two infantry battalions. Results for the entire surveyed population are presented elsewhere (Army Public Health Center (APHC) 2017). This analysis was specific to reported injuries during road marching.

The survey asked respondents to self-assess their occupational lifting and aerobic demands. Response options for lifting requirements were categorized as: (1) None, lifting is always less than 10 pounds; (2) light, frequent lifting of 10 pounds, occasionally up to 20 pounds; (3) medium, frequent lifting of 25 pounds, occasionally up to 50 pounds; (4) moderately heavy, frequent lifting of 40 pounds, occasionally up to 80 pounds; (5) heavy, frequent lifting of 50 pounds, occasionally up to 100 pounds; (6) very heavy, frequent lifting of 50 pounds, occasionally over 100 pounds. The following occupational aerobic demands response categories were provided: (1) None: Not physical, activities are sedentary; (2) light, limited or occasional strenuous high energy activities; (3) moderate, most days involve strenuous high energy activities; (4) high, every day involves long periods of strenuous high energy activities.

Data were exported from the survey software into the Statistical Package for the Social Sciences (SPSS®) Version 19.0 for analysis. After the survey was administered, age and rank were grouped into accepted categories. Occupations were grouped as Combat Arms, Combat Services, or Combat Services Support, based on respondents' reported occupational specialty and consistent

with DA categorization (Department of the Army 2011). Body Mass Index (BMI) was calculated from self-reported height and weight data and categorized according to Army and Centers for Disease Control classifications for underweight, normal, low overweight, high overweight, and obese (Centers for Disease Control and Prevention 2015; Department of the Army 2006). Current cigarette smokers were defined as those who reported smoking more than 100 cigarettes in their lifetime and smoking in the past 30 days. Current smokeless tobacco users and e-cigarette users were defined as those Soldiers who reported using these products in the previous 30 days. Former users of tobacco products were those who reported but did not use in the previous 30 days.

Variables for height, APFT performance, and the frequency of PT activities were divided into tertiles to represent approximately equal response categories. Reported durations of unit PT activities were grouped by half hour. Because there were generally shorter durations of personal PT activities reported, those were grouped by quarter hour. Total weekly running mileage for both unit and personal PT was calculated based on average reported frequency and distance of running. If frequency or duration was reported for a PT activity, but the other was not reported, the missing response was labeled as 'unknown' but were still included in the analysis. Using responses to the three survey questions about road marching participation (average monthly frequency, average distance per session, and average weight carried per session), additional variables were calculated. Total miles per month marched were divided into three groups; low (≤19 miles per month), moderate (20-32 miles per month), and high mileage (≥33 miles per month), percentage of body weight carried per session, and average pound-miles per month were considered.

Descriptive statistics were calculated for demographics and activities associated with injuries. Injury rates and injury RRs based on exposure time were calculated for road marching and running. A Pearson chi-square analysis of associations was conducted to compare the demographic makeup of Soldiers injured and uninjured during road marching. An independent samples t-test was used to investigate statistically significant differences in training activities among those who were injured and uninjured while participating in low, moderate, and high mileage road marching.

In preparation for multivariable risk factor analysis, the reported occurrence of at least one road marching injury during the six months prior to the survey was coded as a binary variable for each respondent. An injury was considered a road marching injury if the respondent indicated that the activity associated with the injury was road marching. To assess risk factors for road marching injuries, univariate odds ratios and 95 percent confidence intervals (CI) are reported for each risk factor variable. Variables were entered into a backward-stepping multivariable logistic regression analysis if they were found to be significant ($p \leq 0.10$) in the unadjusted logistic regression assessment for injury risk. Odds ratios and 95 percent CIs for variables remaining in the final adjusted models ($p \leq 0.05$) are reported. The adjusted analyses were stratified by reported road marching exposure, defined as the average road marching miles per month, based on existing literature that suggests the potential for varying injury risk factors for different combinations of road marching frequency and distance (APHC(P) 2016; Orr et al. 2016a).

6 Results

6.1 Leading Injury Activities

The questionnaire had 831 respondents, 310 of whom (37 percent) reported a total of 412 injuries (APHC 2017). The average respondent was 25 years old with a Body Mass Index (BMI) of 25.6 (APHC 2017). As shown in Table 1, road marching was the reported activity associated with 23 percent of injuries, second only to running for physical training. These road marching injuries

resulted in 49 injuries with temporary duty restrictions (21 percent of reported restrictions) and 1,795 limited duty days (20 percent of reported limited duty days) during the 6 months prior to survey administration.

Table 1. Reported Activities Associated with All Injuries in an Infantry Brigade (n=831 Soldiers)

Activity associated with injury	Total injuries n (%)	Total injuries resulting in limited duty n (%)	Total limited duty days	Average number of limited duty days per injury
Physical training (running)	113 (27%)	74 (32%)	2,514 (28%)	31
Road marching	96 (23%)	49 (21%)	1,840 (20%)	33
Physical training (weight lifting)	43 (10%)	19 (8%)	678 (8%)	36
Lifting or moving heavy objects	35 (8%)	18 (8%)	957 (11%)	49
Other physical training	31 (8%)	17 (7%)	482 (5%)	28
Sports/recreation	20 (5%)	14 (6%)	378 (4%)	27
Walking or hiking	13 (3%)	5 (2%)	204 (2%)	41
Riding, driving, or moving in/around a motorized vehicle	11 (3%)	8 (3%)	489 (5%)	61
Stepping/climbing	8 (2%)	4 (2%)	154 (2%)	39
Combatives training	7 (1%)	3 (1%)	290 (3%)	97
Repairing or maintaining equipment	3 (<1%)	1 (<1%)	14 (<1%)	14
Other	23 (6%)	17 (7%)	777 (9%)	46
Unknown	9 (2%)	3 (1%)	208 (2%)	-
Total	**412 (100%)**	**232**	**8,985**	**-**

Most respondents (89 percent, n=736) reported participation in road marching with their unit during the 6 months prior to survey administration. Among the respondents who participated, the average frequency reported was five times per month and the average distance reported was 7.4 miles per session. Over a period of 6 months, this is an estimated 163,392 total miles marched by all Soldiers who completed the survey. The average weight carried was reported to be 44 pounds (20 kilograms) per session.

While running resulted in the greatest number of injuries, exposure should be taken into account when considering injury risk. Table 2 compares the rates of injury by miles of exposure for running and road marching with a load. A total of 762 respondents reported running during unit PT (92 percent) on average 3 times per week for an average of 4.0 miles per session. A total of 621 respondents reported running during personal PT (75 percent) on average 2 times per week for an average of 3.4 miles per session; extrapolating to 26 weeks gives an estimated 347,537 miles run during unit and personal PT by Soldiers in these two battalions over 6 months. When accounting

for miles of exposure in this manner, road marching was associated with higher rates of all injuries (RR=1.81, 95 percent CI 1.38-2.37) and injuries resulting in limited duty (RR=1.41, 95 percent CI 0.98-2.02) when compared to running. The demographics and personal characteristics of those who were injured during road marching were not statistically different than those respondents who participated in road marching but did not report an associated injury (p>0.05).

Table 2. Injury Rates Per Miles of Exposure, Running and Road Marching (n=831 Soldiers)

Activity associated with injury	Total injuries in prior six months	Total injuries resulting in limited duty in prior six months	Total miles exposed in prior six months	Rate of injury per 10,000 miles	Rate of injury per 10,000 miles resulting in limited duty per mile	Relative risk of injury (95% CI)	Relative risk of injury resulting in limited duty (95% CI)
Running	113	74	347,537	3.3	2.1	-	-
Road marching	96	49	163,392	5.9	3.0	1.81 (1.38-2.37)	1.41 (0.98-2.02)

It has been suggested that the risk of injury during road marching may be affected by the cumulative effects of participation in other load-bearing activities (Orr et al. 2016a). Table 3 shows the average responses to survey questions regarding road marching, distance running, resistance training, and occupational physical demands, among those who did and did not report a road marching injury. Responses were further stratified by the total road marching distance marched per month (low, moderate, and high mileage). Among all respondents who participated in road marching, those who were injured reported carrying a significantly heavier load, participating in less distance running, and conducting more resistance training sessions, compared to those who were uninjured (p≤0.05). As average road marching distance increased, so did the average load carried, running frequency and mileage, and the frequency and duration of participation in resistance training. Those respondents injured during road marching carried more weight on average than their counterparts who were not injured during road marching. Soldiers who marched the greatest distance per month (≥33 miles) and experienced a road marching-related injury reported a greater frequency of resistance training and more time spent per week participating in resistance training.

Table 3. Comparison of Weight-bearing Activities among Road Marching Participants by Injury Status (n=736 Soldiers)

Road march groups by distance	Injured during road march	Road marching per month (average sessions ±SD)	Road march distance per session (average miles ±SD)	Weight carried per road march session (average lbs (kg) ±SD)	Distance running per week* (average sessions ±SD)	Total running distance per week (average miles ±SD)*	Resistance training sessions per week* (average sessions ±SD)	Weekly time spent resistance training (average minutes ±SD)*	Occupational lifting demands**	Occupational aerobic demands**
All road march participants	72 injured	5.3 ± 4.1	7.1 ± 3.2	**49 (22) ± 15 (7)†**	**4.2 ± 1.7†**	15.8 ± 9.8	**3.9 ± 3.3†**	154 ± 199	50-100+ lbs (26%)	Often strenuous (58%)
	664 not injured	4.7 ± 3.5	7.5 ± 3.5	43 (20) ± 12 (5)	4.6 ± 2.2	17.7 ± 11.0	3.5 ± 2.8	136 ± 169	40-80 lbs (35%)	Often strenuous (60%)
Low mileage (1-19 miles per month)	21 injured	2.3 ± 1.1	5.8 ± 3.1	43 (20) ± 16 (7)	3.7 ± 1.5	12.7 ± 5.9	2.7 ± 3.3	95 ± 110	25-50 lbs (24%) 40-80 lbs (24%)	Often strenuous (62%)
	219 not injured	2.4 ± 1.2	6.5 ± 3.9	40 (18) ± 11 (5)	4.1 ± 2.1	14.5 ± 10.6	3.1 ± 2.6	107 ± 132	25-50 lbs (34%)	Often strenuous (57%)
Moderate mileage (20-32 miles per month)	24 injured	4.3 ± 0.6	6.1 ± 1.2	48 (22) ± 12 (5)	4.1 ± 1.8	13.8 ± 5.8	3.9 ± 2.6	107 ± 100	40-80 lbs (25%)	Often strenuous (63%)
	245 not injured	4.0 ± 0.9	6.6 ± 2.1	44 (20) ± 12 (5)	4.5 ± 2.1	16.8 ± 8.6	3.7 ± 2.8	140 ± 161	40-80 lbs (37%)	Often strenuous (61%)
High mileage (≥33 miles per month)	27 injured	8.6 ± 5.0	9.0 ± 3.6	53 (24) ± 14 (7)	4.6 ± 1.7	20.0 ± 13.4	**4.9 ± 3.7†**	**241 ± 279†**	50-100+ lbs (44%)	Often strenuous (52%)
	200 not injured	8.1 ± 4.4	9.6 ± 3.4	46 (21) ± 12 (5)	5.2 ± 2.3	22.4 ± 12.5	3.7 ± 3.1	163 ± 205	40-80 lbs (37%)	Often strenuous (61%)

Legend:
SD= Standard deviation
*Unit and personal PT participation combined
**Self-assessed categories, no standard deviation, most common response reported
†Average responses among injured and uninjured were significantly different (p≤0.05)

6.2 Injured Body Regions and Injury Types Reported During Road Marching

The injury types and injured body areas reported during road marching are shown in Table 4, along with the associated number of limited duty days experienced as a result. Back injuries were most frequently reported (26 percent), followed by knee injuries (23 percent) and ankle injuries (18 percent). The most predominant type of injury was sprains/strains (46 percent). "Other" injury type categories listed under each body area represent unspecified responses and/or injury type survey response categories that received only one response. The most commonly cited mechanisms of injury during road marching (data not shown) were overuse/repetitive activity (60 percent), single session overexertion/over-extension (19 percent), and falling (6 percent).

Table 4. Road Marching Injuries: Injury Types By Body Region (n=96 Injuries)

Injured Body Region	Total injuries (%)	Total injuries resulting in limited duty days	Total limited duty days	Average number of limited duty days per injury
Back injuries	**25 (26%)**			
Lower back sprain/strain	8	3	75	25
Lower back nerve injury	2	1	7	7
Other lower back injury	10	5	155	17
Upper back sprain/strain	3	1	14	14
Other upper back injury	2	0	-	-
Knee injuries	**22 (23%)**			
Sprain/strain	12	6	87	15
Tear	4	4	195	49
Other knee injury	6	5	307	61
Ankle injuries	**17 (18%)**			
Sprain/strain	8	0	-	-
Tear	3	2	44	22
Fracture	3	1	276	276
Other ankle injury	3	1	20	20
Foot injuries	**7 (7%)**			
Sprain/strain	4	1	14	14
Other foot injury	3	1	10	10
Leg injuries	**7 (7%)**			
Upper leg sprain/strain	2	2	17	9
Other lower leg injury	5	3	97	32
Shoulder injuries	**6 (6%)**			
Tear	2	2	120	60
Sprain/strain	2	2	21	11
Other shoulder injury	2	1	30	30
Neck nerve injuries	**3 (3%)**	**1**	**10**	**10**
Groin injuries	**3 (3%)**	**3**	**150**	**50**
Heat injuries	**3 (3%)**	**1**	**14**	**14**
Hip injuries	**2 (2%)**	**1**	**60**	**60**
Injuries not otherwise specified	**1 (1%)**	**1**	**13**	**13**

6.3 Factors Associated with Road Marching Injuries

Of the 96 unique injuries reported by 83 Soldiers during road marching, injuries reported by 11 Soldiers were not included in risk factor analysis because those respondents did not indicate participation in unit PT and/or did not provide information about the average road marching frequency, distance marched, and/or weight carried. Since road marching exposure during unit training was the desired exposure, those who did not provide additional details could not be appropriately analyzed. A total of 72 Soldiers injured during road marching were analyzed.

Table 5 shows the unadjusted logistic regression analysis results when demographic, personal characteristics, fitness, tobacco use, physical job requirements, running resistance training, and loaded march participation variables were considered for all road marching participants (n=736). This univariate analysis suggests that the following factors are associated with injury during road marching:

- Being an officer,
- Holding a combat arms occupation,
- Being a current user of smokeless tobacco,
- Having very heavy occupational lifting requirements,
- Having strenuous occupational aerobic activity requirements,
- Running less than 4 miles per week for personal PT,
- Participating in resistance training more than three times per week during unit PT,
- Conducting resistance training for 31–60 minutes per session during unit PT,
- Participating in resistance training during personal PT for an average of ≤one or ≥three times per week,
- Carrying more than 50 pounds per session during road marching,
- Carrying more than 26 percent of one's body weight per road marching session, and
- Accumulating more than 1473 pound-miles per month during road marching.

Table 5. Unadjusted Factors Associated with Road Marching Injuries (n=736 Soldiers)

Variable category			Total n	% with road marching injury	Odds Ratio (95% CI)	p-values
Demographics and personal characteristics	**Age**	≤25	422	8%	1.00	
		26-34	264	11%	1.36(0.81-2.29)	0.24
		≥35	***50***	***16%***	***2.11(0.92-4.84)***	***0.08***
	Gender	Male	732	10%	n/a	>0.99
		Female	4	0%	1.00	
	Height (feet and inches)	≤5'8"	232	11%	1.36(0.74-2.51)	0.33
		5'9"-5'11"	264	10%	1.17(0.64-2.16)	0.61
		≥6'0"	235	9%	1.00	
		Not answered	5	0%	n/a	>0.99
	Rank	E1-E4	482	8%	1.00	
		E5-E9	183	11%	1.43(0.82-2.50)	0.21
		O1-O5	***71***	***15%***	***2.03(0.99-4.16)***	***0.06***
	Battalion	Battalion X	300	8%	1.00	
		Battalion Y	436	11%	1.42(0.85-2.38)	0.18
	Occupation group	Combat Arms	615	10%	2.02(0.79-5.16)	0.14
		Combat Services	28	11%	2.09(0.47-9.35)	0.34
		Combat Ser vices Support	92	5%	1.00	
		Not answered	1	0%	n/a	>0.99
Fitness	BMI	Underweight (≤18.5)	6	0%	n/a	>0.99
		Normal (18.6-24.9)	263	10%	1.05(0.59-1.87)	0.86
		Low overweight (25-27.5)	255	10%	1.00	
		High overweight (27.6-29.9)	137	9%	0.88(0.43-1.82)	0.74
		Obese (≥30)	65	11%	1.11(0.46-2.69)	0.82
		Not able to calculate	10	10%	1.02(0.12-8.41)	0.98
	APFT Pushup repetitions	≤59	211	10%	1.18(0.64-2.21)	0.59
		60-71	246	9%	1.00	
		≥72	258	11%	1.24(0.69-2.23)	0.47
		Not reported	21	0%	n/a	>0.99

Table 5. Unadjusted Factors Associated with Road Marching Injuries (n=831 Soldiers) (cont'd.)

Variable category			Total n	% with road marching injury	Odds Ratio (95% CI)	p-values
Fitness	APFT Sit-up repetitions	≤64	207	11%	1.35(0.73-2.51)	0.34
		65-74	238	12%	1.52(0.84-2.73)	0.17
		≥75	272	8%	1.00	
		Not reported	19	0%	n/a	>0.99
	APFT Two-mile run time (minutes)	≥15.00	202	12%	1.38(0.75-2.53)	0.30
		13.85-14.99	251	10%	1.08(0.59-1.98)	0.80
		≤13.84	237	9%	1.00	
		Not reported	46	0%	n/a	>0.99
Tobacco use	Cigarette smoking status	Current smoker	218	11%	1.24(0.71-2.15)	0.45
		Former smoker	116	12%	1.44(0.75-2.78)	0.28
		Never smoked	402	9%	1.00	
	Smokeless tobacco status	***Current user***	***223***	***13%***	***1.58(0.92-2.71)***	***0.10***
		Former user	141	9%	1.12(0.57-2.20)	0.75
		Never used	372	8%	1.00	
	E-cigarette status	Current smoker	78	9%	0.91(0.40-2.07)	0.81
		Former smoker	139	10%	1.03(0.55-1.92)	0.93
		Never smoked	519	10%	1.00	
Physical job requirements	**Lifting required for job (weight in pounds)**	0-20	66	11%	1.82(0.68-4.92)	0.24
		25-50	180	6%	1.00	
		40-80	251	7%	1.12(0.51-2.44)	0.78
		50-100	***140***	***13%***	***2.27(1.03-4.97)***	***0.04***
		50-100+	***99***	***19%***	***3.65(1.66-8.03)***	***<0.01***
	Intensity of aerobic activity required for job	Sedentary/ infrequently strenuous	180	6%	1.00	
		Often strenuous	439	10%	1.80(0.88-3.67)	0.11
		Always strenuous	***117***	***17%***	***3.51(1.58-7.79)***	***<0.01***
Running mileage per week	Average running per week during unit PT (miles)	0/no participation	6	17%	2.08(0.23-18.51)	0.51
		1-8	285	9%	1.00	
		9-12	254	11%	1.24(0.70-2.19)	0.47
		≥13	187	10%	1.18(0.63-2.20)	0.61
		unknown	4	0%	n/a	>0.99

Table 5. Unadjusted Factors Associated with Road Marching Injuries (n=831 Soldiers) (cont'd.)

Variable category			Total n	% with road marching injury	Odds Ratio (95% CI)	Category p-values
Running mileage per week	**Average running per week during personal PT (miles)**	***0/no participation***	***163***	***12%***	***2.35(1.06-5.21)***	***0.04***
		<1-4	***193***	***13%***	***2.77(1.30-5.92)***	***<0.01***
		4.5-9	183	9%	1.82(0.81-4.09)	0.15
		≥10	188	5%	1.00	
		unknown	9	0%	n/a	>0.99
Resistance training participation	**Frequency of resistance training during unit PT (times/week)**	0/no participation	80	13%	1.89(0.85-4.23)	0.12
		<1-1	285	7%	1.00	
		2	167	10%	1.40(0.71-2.79)	0.33
		≥3	***175***	***14%***	***2.11(1.13-3.94)***	***0.02***
		unknown	29	7%	0.98(0.22-4.43)	0.98
	Average resistance training duration during unit PT (minutes/ session)	***0/no participation***	***80***	***13%***	***2.04(0.88-4.69)***	***0.10***
		1-30	244	7%	1.00	
		31-60	***278***	***13%***	***2.05(1.11-3.81)***	***0.02***
		≥61	129	9%	1.33(0.60-2.95)	0.49
		unknown	5	0%	n/a	>0.99
	Frequency of resistance training during personal PT (times/week)	***0/no participation***	***223***	***11%***	***2.78(0.94-8.22)***	***0.07***
		<1-1	151	9%	2.25(0.72-7.05)	0.17
		2	92	4%	1.00	
		≥3	***236***	***11%***	***2.61(0.88-7.71)***	***0.08***
		unknown	34	12%	2.93(0.69-12.46)	0.15
	Average duration of resistance training during personal PT (minutes/ session)	***0/no participation***	***257***	***11%***	***3.82(0.89-16.45)***	***0.08***
		1-15	172	8%	2.45(0.54-11.19)	0.25
		16-30	62	3%	1.00	
		≥31	177	10%	3.40(0.77-15.08)	0.11
		unknown	***68***	***15%***	***5.17(1.09-24.63)***	***0.04***
Road marching participation	**Frequency of road marching (times/month)**	1-3	229	9%	1.11(0.59-2.07)	0.75
		4	289	8%	1.00	
		≥5	***218***	***13%***	***1.78(1.00-3.16)***	***0.05***
	Average road marching distance (miles/session)	1-6	393	10%	1.00	
		7-8	167	12%	1.20(0.68-2.12)	0.53
		≥8.5	176	7%	0.65(0.33-1.26)	0.20

Table 5. Unadjusted Factors Associated with Road Marching Injuries (n=831 Soldiers) (cont'd.)

Variable category			Total n	% with road marching injury	Odds Ratio (95% CI)	Category p-values
Road marching participation	Total road marching distance (miles/month)	1-19	240	9%	1.00	
		20-32	269	9%	1.02(0.55-1.89)	0.95
		≥33	227	12%	1.41(0.77-2.57)	0.27
	Average weight worn during road march (lbs/session)	1-39	270	6%	1.00	
		40-49	248	9%	1.66(0.84-3.27)	0.15
		≥50	***218***	***16%***	***3.25(1.73-6.13)***	***<0.01***
	Average percent of body weight worn during road march (%/session)	<1-20	234	7%	1.00	
		21-25	228	8%	1.24(0.62-2.47)	0.54
		≥26	***271***	***13%***	***2.09(1.13-3.87)***	***0.02***
		Not able to calculate	3	33%	6.81(0.59-79.23)	0.13
	Average road march pound-miles per month (lbs-miles/month)	1-750	248	8%	1.00	
		751-1472	243	7%	0.91(0.47-1.77)	0.79
		≥1473	***245***	***14%***	***1.84(1.03-3.29)***	***0.04***

Notes:
Significant variable categories (p≤0.10) are bolded.
'Unknown' training categories represent participation responses without further details provided.

Because the average weight carried and pound-miles per month road marching variables were both found to be correlated with the percentage of body weight carried during road marching, only average percent of body weight carried was included in the adjusted models, since current military guidance recommends the fraction of body weight as a quantitative parameter for weight limits during road marching (APHC (P) 2016; Department of the Army 1990; NATO-RTO 2009).

The results of multivariable regression analyses are shown in Tables 6–9. For those individuals reporting the lowest amount of road marching (≤19 miles per month), holding a noncommissioned officer rank (E5-E9) or being a current smokeless tobacco user were associated with almost 4 times the odds of injury compared to lower enlisted respondents and those who did not report smokeless tobacco use (Table 6). For those who road marched an average of 20–32 miles per month, two factors were associated with road marching injuries (Table 7): officer rank (6 times the odds of injury compared to enlisted) and not participating in running for personal PT (17 times the odds of injury compared to those who ran at least 10 miles per week). For those who reported road marching the longest total distances each month (≥33 miles), having a job that requires heavy lifting, participating in running during personal PT but for less than 4 miles per week, and participating in resistance training for more than 30 minutes per session during personal PT were

associated with road marching injuries (Table 8). Wearing more than 26 percent of one's body weight during road marching was marginally associated with road marching injuries.

Table 9 shows regression analysis results when all respondents who indicated low, moderate, or high mileage road marching were included. The following factors were associated with road marching injuries among all road marching participants:

- Age 35 and over (almost three times the odds of injury compared to respondents age 35 and under),
- Having a job that requires heavy lifting (three times the odds of injury compared to those with less rigorous occupational lifting requirements),
- Road marching five or more times per month (twice the odds of injury compared to those who marched less),
- Running less than 5 miles per week for personal PT (at least three times the odds of injury compared to those who ran at least 10 miles per week), and
- Wearing more than 25 percent of one's body weight when road marching (twice the odds of injury compared to those who carried 20 percent or less).

Table 6. Adjusted Factors Associated with Road Marching Injuries among Soldiers who Road Marched 1-19 miles/month (n=240 Soldiers)

Variable category		Total n	% with road march injury	Odds Ratio (95% CI)	Category p-values
Rank	E1-E4	165	5%	1.00	
	E5-E9	***47***	***19%***	***3.94(1.43-10.80)***	***<0.01***
	O1-O5	28	11%	2.40(0.59-9.84)	0.22
Smokeless tobacco status	***Current user***	***66***	***17%***	***3.39(1.43-10.80)***	***<0.01***
	Former user	45	7%	1.16(0.28-4.80)	0.84
	Never used	129	5%	1.00	

Notes:
Significant variable categories (p≤0.05) are bolded.
Variables entered into logistic regression: Age, Rank, Smokeless tobacco status, Amount of lifting required for job, Amount of aerobic activity required for job, Average running mileage per week during personal PT, Average frequency of resistance training during unit PT, Average duration of resistance training during unit PT, Average frequency of resistance training during personal PT, Average duration of resistance training during personal PT, Average frequency of road marching, Average percent of body weight worn during road march.

Table 7. Adjusted Factors Associated with Road Marching Injuries among Soldiers who Road Marched 20-32 Miles/Month (n=269 Soldiers)

Variable category		Total n	% with road marching injury	Odds Ratio (95% CI)	Category p-values
Rank	E1-E4	164	9%	1.47(0.46-4.73)	0.52
	E5-E9	73	5%	1.00	
	O1-O5	***32***	***19%***	***6.04(1.46-24.97)***	***0.01***
Average running per week during personal PT (miles)	***0/no partic.***	***60***	***17%***	***17.05(1.96-148.20)***	***0.01***
	<1-4	71	10%	7.52(0.87-64.94)	0.07
	4.5-9	77	8%	5.62(0.64-49.39)	0.12
	≥10	58	2%	1.00	
	unknown	3	0%	n/a	>0.99

Notes:
Significant variable response categories (p≤0.05) are bolded.
Variables entered into logistic regression: Age, Rank, Smokeless tobacco status, Amount of lifting required for job, Amount of aerobic activity required for job, Average running mileage per week during personal PT, Average frequency of resistance training during unit PT, Average duration of resistance training during unit PT, Average frequency of resistance training during personal PT, Average duration of resistance training during personal PT, Average frequency of road marching, Average percent of body weight worn during road march.

Table 8. Adjusted Factors Associated with Road Marching Injuries among Soldiers who Road Marched Greater than 32 Miles/Month (n=227 Soldiers)

Variable category		Total n	% with road marching injury	Odds Ratio (95% CI)	Category p-values
Lifting required for job (weight in pounds)	0-20	12	8%	2.24(0.15-32.68)	0.55
	25-50	45	4%	1.00	
	40-80	80	8%	1.49(0.25-8.84)	0.66
	50-100	53	11%	2.85(0.49-16.73)	0.25
	50-100+	***37***	***32%***	***10.50(1.92-57.46)***	***<0.01***
Average running mileage per week during personal PT	0/no partic.	41	7%	2.67(0.48-14.85)	0.26
	<1-4	***41***	***24%***	***8.17(2.16-30.89)***	***<0.01***
	4.5-9	60	13%	2.58(0.70-9.48)	0.15
	≥10	84	7%	1.00	
	unknown	1	0%	n/a	>0.99
Average duration of resistance training during personal PT (minutes/session)	0/no partic.	78	12%	n/a	>0.99
	1-15	51	4%	1.00	
	16-30	16	7%	1.87(0.18-19.68)	0.60
	≥31	***68***	***16%***	***3.47(1.12-10.76)***	***0.03***
	unknown	14	29	3.18(0.66-15.31)	0.15
Average percent of body weight worn during road march (%/session)	<1-20	49	4%	1.00	
	21-25	71	8%	1.29(0.22-7.53)	0.78
	≥26	105	17%	4.41(0.83-23.34)	0.08
	Not able to calculate	2	50%	n/a	n/a

Notes:
Significant variable categories (p≤0.05) are bolded.
'Unknown' training categories represent participation responses without further details provided.
Variables entered into logistic regression: Age, Rank, Smokeless tobacco status, Amount of lifting required for job, Amount of aerobic activity required for job, Average running mileage per week during personal PT, Average frequency of resistance training during unit PT, Average duration of resistance training during unit PT, Average frequency of resistance training during personal PT, Average duration of resistance training during personal PT, Average frequency of road marching, Average percent of body weight worn during road march.

Table 9. Adjusted Factors Associated with Road Marching Injuries among Soldiers who Road Marched (n=736 Soldiers)

Variable category		Total n	% with road marching injury	Odds Ratio (95% CI)	Category p-values
Age	≤25	422	8%	1.00	
	26-34	264	11%	1.54(0.89-2.66)	0.12
	≥35	***50***	***16%***	***2.89(1.17-7.16)***	***0.02***
Lifting required for job (weight in pounds)	0-20	66	11%	1.83(0.66-5.07)	0.25
	25-50	180	6%	1.00	
	40-80	251	7%	0.98(0.44-2.18)	0.95
	50-100	140	13%	1.91(0.84-4.34)	0.12
	50-100+	***99***	***19%***	***3.43(1.50-7.85)***	***<0.01***
Frequency of road marching (times/month)	1-3	229	9%	1.38(0.71-2.67)	0.35
	4	289	8%	1.00	
	≥5	***218***	***13%***	***2.11(1.14-3.91)***	***0.02***
Average running per week during personal PT (miles)	***0/no participation***	***163***	***12%***	***3.56(1.49-8.54)***	***<0.01***
	<1-4	***193***	***13%***	***4.14(1.85-9.25)***	***<0.01***
	4.5-9	183	9%	2.16(0.93-5.00)	0.07
	≥10	188	5%	1.00	
	unknown	9	0%	n/a	>0.99
Average percent of body weight worn during road march (%/session)	<1-20	234	7%	1.00	
	21-25	228	8%	1.15(0.56-2.36)	0.71
	≥26	***271***	***13%***	***2.09(1.08-4.05)***	***0.03***
	Not able to calculate	3	33%	9.28(0.73-117.53)	0.09

Notes:
Significant variable categories (p≤0.05) are bolded.
'Unknown' training categories represent participation responses without further details provided.
Variables entered into logistic regression: Age, Rank, Smokeless tobacco status, Amount of lifting required for job, Amount of aerobic activity required for job, Average running mileage per week during personal PT, Average frequency of resistance training during unit PT, Average duration of resistance training during unit PT, Average frequency of resistance training during personal PT, Average duration of resistance training during personal PT, Average frequency of road marching, Average percent of body weight worn during road march.

Pound-miles per month, the product of the reported number of miles marched per month and average pounds carried during road marching, were calculated for all respondents. When entered into the multivariable model with all road marching participants replacing average percent of body weight carried, similar results were observed (Table 10). Both road marching variables were not entered together, as they are correlated. The following factors were found to be associated with road marching injuries when average percent body weight carried was replaced with pound-miles per month in the multivariable model:

- Officer rank, instead of older age (twice the odds of injury compared to lower enlisted ranks),
- Having a job that requires heavy lifting (three times the odds of injury compared to those with less rigorous occupational lifting requirements),
- Running less than 5 miles per week for personal PT (at least three times the odds of injury compared to those who ran at least 10 miles per week), and
- Completing more than 1473 pound-miles per month (twice the odds of injury compared to those who carried 20 percent or less).

Table 11 compares the risk of injury when ≥1473 pound-miles per month were reported to when less is reported. Injury rates were significantly greater among those with ≥1473 pound-miles per month (RR=1.92, 95 percent CI 1.49-2.46) and injuries resulting in limited duty (RR=1.68, 95 percent CI 1.17-2.41) when compared to those who reported <1473 pound-miles. Because the each Soldier could report up to two injuries, and some reported multiple injuries during road marching, the number of road marching injuries exceeds the number of Soldiers injured during road marching that is shown in Table 10.

Table 10. Adjusted Factors Associated with Road Marching Injuries among Soldiers who Road Marched (n=736 Soldiers, pound-miles variable substituted)

Variable category		Total n	% with road marching injury	Odds Ratio (95% CI)	Category p-values
Rank	E1-E4	482	8%	1.00	
	E5-E9	183	11%	1.45(0.81-2.61)	0.22
	O1-O5	***71***	***15%***	***2.37(1.10-5.08)***	***0.03***
Lifting required for job (weight in pounds)	0-20	66	11%	1.73(0.62-4.82)	0.29
	25-50	180	6%	1.00	
	40-80	251	7%	1.03(0.46-2.29)	0.94
	50-100	140	13%	1.81(0.80-4.08)	0.16
	50-100+	***99***	***19%***	***3.47(1.53-7.87)***	***<0.01***
Average running per week during personal PT (miles)	***0/no participation***	***163***	***12%***	***3.26(1.42-7.51)***	***<0.01***
	<1-4	***193***	***13%***	***3.63(1.64-8.04)***	***<0.01***
	4.5-9	183	9%	2.00(0.87-4.59)	0.10
	≥10	188	5%	1.00	
	unknown	9	0%	n/a	>0.99
Pound-miles marched per month	1-750	248	8%	1.00	
	751-1472	243	7%	0.93(0.46-1.85)	0.82
	≥1473	***245***	***14%***	***1.99(1.05-3.79)***	***0.04***

Notes:
Significant variable categories (p≤0.05) are bolded.
'Unknown' training categories represent participation responses without further details provided.
Variables entered into logistic regression: Age, Rank, Smokeless tobacco status, Amount of lifting required for job, Amount of aerobic activity required for job, Average running mileage per week during personal PT, Average frequency of resistance training during unit PT, Average duration of resistance training during unit PT, Average frequency of resistance training during personal PT, Average duration of resistance training during personal PT, Average frequency of road marching, Pound-miles marched per month.

Table 11. Road Marching Injury Rates Per Pound-Miles Reported (n=736 Soldiers)

Pound-miles per month	Total number of road marching injuries in prior six months	Total injuries resulting in limited duty in prior six months	Total number who reported road marching participation	Rate of road marching injury per 1,000 Soldiers	Rate of road marching injury per 1,000 Soldiers resulting in limited duty	Relative risk of injury (95% CI)	Relative risk of injury resulting in limited duty (95% CI)
<1473	41	22	491	83	44	-	-
≥1473	39	18	245	159	73	1.92 (1.49-2.46)	1.68 (1.17-2.41)

7 Discussion

7.1 Road Marching Injuries

The percentage of Soldiers reporting a training-related road marching injury was comparable to what has been found for basic trainees (Knapik et al. 1999) and infantry Soldiers (Reynolds et al. 1999) in other survey-based investigations of military injuries. In a previous study, road marching was also second to physical training with 23 percent of injuries in a population of Soldiers in Initial Entry Training (Knapik et al. 2013).

The most commonly injured body parts during road marching in this infantry population were the back, knees, and ankles, representing two thirds of the road marching injuries (Table 4). This is similar to results of other military studies that have also identified the back and lower extremities as commonly injured areas during road march training or deployment situations where loads are carried (Andersen et al. 2016; APHC (Prov) 2016; Knapik and Reynolds 2012; Knapik et al. 1992; Knapik 2013; Knapik and Reynolds 2015; Konitzer et al. 2008; Orr et al. 2016b; Orr et al. 2015; Roy et al. 2012a; Roy et al. 2013; Roy et al. 2012b; Sanders et al. 2005). As Knapik and Reynolds explain, these injuries likely occur during road marching due to additional stress on the trunk, which leads to increased torque on the spine and a greater range of motion in the knee (Knapik and Reynolds 2015). Sprains and strains were the predominant injury types resulting from road marching in this study, which has also regularly been cited in other military populations (Knapik et al. 1992; Ruscio et al. 2010; Sell et al. 2009). Though shoulder and upper back injuries were not common in this population, brachial plexus “rucksack” palsy has often been reported in association with road marching as a result of compression from backpack straps (Knapik et al. 2004; NATO-RTO 2009; Orr et al. 2014).

Though the ankle hasn’t often been reported as a commonly injured body part during individual road marching events (Knapik et al. 1992; Reynolds et al. 1999), ankle injuries represented 28 percent of injuries reported by recreational hikers and 16 percent of Swiss military load carriage injuries over extended periods of time, which is comparable to the 18 percent of ankle injuries reported by the current survey population during the previous 6 months. The relative lack of ankle injuries during short-term events is likely because these injuries occur due to overuse and cumulative trauma over time (Lobb 2004; Orr et al. 2016a).

While other studies have identified blisters as a common injury that results from road marching (Knapik and Reynolds 2012; Knapik 2013; Knapik and Reynolds 2015; Knapik et al. 1999; NATO-RTO 2009; Reynolds et al. 1999), blisters were not widely reported in this investigation perhaps

because respondents did not consider them among their two most physically limiting injuries. Similarly low occurrences of blisters, coupled with a higher occurrence of lower extremity musculoskeletal injuries, were reported in two studies of Australian military members. The authors of those studies posited that the lack of reported blisters may have been due to differences in road marching terrain, boot wear, data collection methods, and respondents' interpretation of a blister as an injury (Orr et al. 2016b; Orr et al. 2015). Other studies have also captured reports of marching-related pain in addition to, or instead of, specific injuries (Konitzer et al. 2008; Roy et al. 2013; Sanders et al. 2005), but respondents in this survey population did not report that general ailment.

7.2 Road Marching Exposure Factors

The road marching training exposure variables evaluated included the average frequency of road marching each month, the average distance marched per session, and the load weight carried per session. It is recommended in U.S. Army training guidance that Soldiers participate in road marching two to four times per month (US Army Medical Department 2009), but the current population reported a road marching average of five times per month. While the survey data does not indicate a reason for higher than recommended frequencies of road marching in this population, military training activities should be balanced in an attempt to increase fitness and control injury risk (Department of the Army 2012). Scientific literature (Grier et al. 2016; Jones and Hauschild 2015) and military guidance (Department of the Army 2012) have indicated that higher running mileage is associated with higher injury rates, so it is possible that military leaders may be discouraging running during PT and subsequently increasing the frequency of loaded road march training to address that concern (APHC (Prov) 2016). However, compared to running, road marching was found to have a higher relative risk of injury when miles of exposure were considered. Miles of exposure has not been considered before when comparing the injury risk of running and road marching. In light of these results, it is not advisable that sustained endurance running be directly replaced with road marching. This supports recommendations for a graduated, progressive road marching training program that is coordinated with other physical training (APHC (Prov) 2016; Department of the Army 2012; Department of the Army 1990).

This analysis found that 33 percent of survey respondents regularly carried in excess of 25 percent of their body weight during road marching training. Among all road marching participants, carrying a load that was more than 25 percent of one's body weight was associated with twice the odds of injury compared to those who carried a lighter load. These results indicate that the road marching load should be no more than 25 percent of one's body weight; for the average 181-pound (82-kilogram) Soldier in this population; this 25 percent maximum load would be 45 pounds (21 kilograms). As this is not always operationally feasible, reducing the cumulative overloading from both physical training and occupational tasks may help prevent injury.

From a physiological standpoint, the amount of weight that an individual can wear is dependent on body size (Knapik et al. 2004; NATO-RTO 2009; Taylor et al. 2016). Studies have recommended that the load weight be below approximately one-third of one's body weight (Haisman 1988; Quesada et al. 2000; Yu and Lu 1990). The current recommendations for military load carriage from the NATO are 20–30 percent of one's body weight during training in infantry school, and a maximum load of 45 percent of body weight in deployment situations (NATO-RTO 2009). Other studies have recommended optimal load weights ranging from 20 to 50 kilograms (44 to 110 pounds) to minimize energy cost (Pal et al. 2009; Scott and Christie 2004; Yu and Lu 1990) and reduce injury risk (Roy et al. 2012b) as much as possible. The Army Field Manual for road marching recommends maximum loads in combat situations of 48 pounds (22 kilograms) for loads

that include weapons and ammunition, 72 pounds (33 kilograms) for loads that include enough equipment and munitions to last until resupply, and 120 pounds (54 kilograms) up to 150 pounds (68 kilograms) for temporary emergency loads (Department of the Army 1990).

The results of this study support the lowest range of these recommended weights, so reducing the weight of loads to these levels should be considered whenever possible. However, it is acknowledged that for many units this is not practical since operational requirements and equipment have increasingly necessitated heavier loads (APHC (Prov) 2016). Specifically, U.S. Army Soldiers in recent overseas operations have carried loads up to 60 kilograms (130 pounds) due to requirements to wear weapons technology, equipment, and body armor (Dean and DuPont 2003; Knapik et al. 2004; Konitzer et al. 2008; Nindl et al. 2013; NATO-RTO 2009). There remains a need to train personnel so they develop the physical capability to meet these operational needs or reduce the weight or amount of equipment worn (APHC (Prov) 2016). However, it has been proven that drastic increases in carried weight lead to high metabolic costs, increased stress on the musculoskeletal system, altered breathing, reduced thermoregulatory functions, and lower mobility, all of which can lead to an increase in injury risk (Carlton and Orr 2014; Knapik et al. 2004; Roy et al. 2012; Roy et al. 2013; Taylor et al. 2016). While adherence to recommended weight limits may minimize injury risk, the more practical recommendation may be to enforce the gradual increase in weight over time while minimizing weights to that operationally necessary for each unit's mission (APHC (Prov) 2016; Knapik 2014; Knapik and Reynolds 2015; Orr et al. 2010).

When the number of pound-miles per month was considered in the multivariable analysis (Table 10), it was found that a high product of distance and weight is a significant risk factor for road marching injury and a higher overall risk of injury and injury leading to limited duty time (Table 11). This variable has not been considered in previous studies, and these results indicate that both the distance marched and the weight worn have an effect on injury risk. Recent recommendations suggest a 10 percent increase in speed, distance, and weight, increasing distance and weight on alternating days, tailoring maximum road marching distances to unit needs, and gradually progressing these variables over 2–6 months depending on other activities and unit fitness levels (APHC (Prov) 2016).

7.3 Participation in Other Weight-Bearing Activities

Respondents in this population who road marched more miles per month also ran more miles and participated in more resistance training sessions for longer durations. However, those who were injured during road marching carried significantly more weight, ran significantly fewer sessions, and participated in significantly more resistance training sessions than those who were not injured. Among all road marching participants, road marching more than five times per month was associated with twice the odds of road marching injury compared to those who marched less.

Further, the frequency and duration of participation in other weight-bearing activities was found to be associated with road marching injury in multivariable regression analyses (Tables 7–9). Among those who marched the most (≥33 miles per month), participating in resistance training during personal PT for more than 30 minutes per session was associated with road marching injury. Likewise, occupational lifting demands that were reported as heavy (often requiring 50 pounds of lifting, and sometimes requiring over 100 pounds of lifting) were found to be associated with higher road marching injury rates among all respondents who reported road marching, and specifically those who reported road marching 33 miles or more per month. Those who road marched ≥33 miles per month and reported a road marching injury also reported an average of 4 hours (241 minutes) per week spent resistance training during PT (Table 3). These results are supported by

literature that previously recommended a moderate amount of strength training to promote muscular endurance but avoid overtraining injuries (Gabbett 2016; Grier et al. 2013; Kraemer and Szivak 2012). Running less than 4 miles per week during personal PT was also associated with road marching injuries in this study; it has been suggested that Soldiers may be more likely to improve their aerobic endurance during personal PT running because they can choose their own pace (Grier et al., 2017). However, it is also possible that the lower running mileage among those respondents was a result of their road marching injuries.

While aerobic and muscular endurance have generally been found to be protective against military injuries (Grier et al., 2013; Knapik 2014), cumulative effects of overtraining during weight-bearing activities have been shown to lead to higher rates of overuse, and musculoskeletal injuries (Grier et al. 2017; Jones and Hauschild 2015; Kaufman et al. 2000; Knapik et al. 2011; Trank et al. 2001). Program-induced cumulative overload (PICO), or unintentional excessive workloads introduced as part of a physical training program, can lead to fatigue, lower performance, and ultimately injury (Orr et al. 2016a). In addition to unit and personal PT that usually include running and resistance training, basic trainees in one study walked almost 12 kilometers per day (7.3 miles) on post, in between training activities (Knapik et al. 2007); greater distances of this ambulatory activity are associated with higher injury risk (Knapik et al. 2011). Overall injury incidence among Swiss Army infantry trainees significantly decreased when the distance on foot per day and the intensity of daily PT were both gradually increased over time (Roos et al. 2015). Therefore, it is recommended that training programs should be balanced with a variety of muscular strength and resistance training, aerobic training, agility drills, obstacle courses, and balance exercises, along with a sufficient recovery periodization and progressive loading, to promote performance and prevent PICO (Bullock et al. 2010; Department of the Army 2012; Department of the Army 1990; Gabbett 2016; Knapik et al. 2004; Kraemer and Szivak 2012; NATO-RTO 2009; Orr et al. 2016a; Orr et al. 2010; Orr et al. 2014; US Army Medical Department 2009).

7.4 Other Risk Factors

7.4.1 Age

Among all road marching participants, being 35 years or over was significantly associated with road marching injuries. This is consistent with results of previous studies that indicate that older age is a risk factor for all injuries in the Army (Jones and Hauschild 2015), and specifically in deployment situations where heavy loads are often worn (Roy et al. 2012a; Roy et al. 2013).

7.4.2 Rank

Among those respondents who marched the least (≤19 miles per month), senior enlisted ranks were found to have higher odds of injury. While higher rank often corresponds with increased age, and that was true in this population as well, rank was more strongly associated with injury in this population than age. Roy et al. also found a greater relative risk of injury among senior enlisted Soldiers and believe that it may be due to less conditioning, resulting from lower physical demands among managerial occupations often held by senior enlisted Soldiers (Roy et al. 2012a). Officers had higher odds of injury in this population among all road marching participants and those who reported road marching moderate distances (20–32 miles per month), presumably also due to a lack of physical demands in their typical roles.

7.4.3 Smokeless Tobacco Use

Current smokeless tobacco use was associated with higher odds of injury among those in this survey population who reported road marching for fewer than 20 miles per month. Smokeless tobacco use among military members is more than twice as common as among civilians (Peterson et al. 2007). The use of tobacco products (usually cigarettes) has been repeatedly observed to be a risk factor for all injuries in military populations (Jones and Hauschild 2015), and has been a risk factor for road marching injuries in other military populations (Knapik et al. 1999; Reynolds et al. 1999). Knapik et al. explained that vasoconstriction leads to a reduced ability to resist frictional forces in smokeless tobacco users, which could lead to more injuries like foot blisters or sores from load packs (Knapik et al. 1999).

7.5 Strengths and Limitations

This study is one of the first to establish road marching as a leading activity associated with injuries among infantry Soldiers, especially when accounting for miles of exposure. Participation in other weight-bearing physical training activities was found to be associated with road marching injuries, supporting the supposition that cumulative overload from a variety of physically demanding tasks can lead to overuse injuries (Orr et al. 2016a). The identification of a threshold for a hazardous fraction of body weight carried (>26% body weight) confirms previous research and published military guidance (NATO-RTO 2009).

However, there are some limitations to note. To begin, there were only six female respondents in this survey population. Previous studies have considered the effects of load carriage specifically for women (Roy et al. 2015; Simpson et al. 2012). Especially because operational combat roles have recently been opened to women in the U.S. Army (Cone 2016), future studies should investigate ways to minimize injuries among infantry Soldiers of both genders.

This survey was cross-sectional in nature, capturing injury and road marching data at the same point in time. As a result, this analysis describes associations but cannot establish causality. In addition, sel-reported injuries relied on respondents' recall of their two most physically limiting injuries and, therefore, may not have captured some minor injuries. Soldier respondents may not have been aware of differences between common injury types (e.g., sprain vs. tear), so self-reported conditions may differ from medical diagnoses. Self-reported occupational demands, physical training participation, and road marching intensity were not validated and future endeavors should address these limitations. However, a previous investigation of self-reported personal characteristics found a high correlation between self-reported and actual data (Martin et al. 2016).

Finally, the questionnaire did not request circumstantial details like road marching weight or distance progression, speed, terrain, weather, visibility, boot type, and load distribution. Each of these variables, considered alone and in conjunction with each other, can have a significant impact on energy expenditure and injury risk during road march training (Department of the Army 1990; NATO-RTO 2009; Pandolf et al. 1976). Increasing road marching speed by 0.5 kilometers/hour (0.3 miles/hour) or increasing the incline of the road marching surface by 1 percent has been found to have the same energy expenditure as increasing the mass carried by 10 kilograms (22 pounds) (Orr et al. 2012), so considering speed and incline would be beneficial for future investigations. The distribution of the carried load has been found to impact the gait and musculoskeletal impact of the carrier (Knapik et al. 2004; Taylor et al. 2016; Yang et al. 2015). Therefore, double packs that

distribute the load equally to the front and back of the body, closer to the body's center of gravity, have been suggested for Soldiers to more efficiently carry the necessary mass (Knapik and Reynolds 2015; Knapik et al. 2004; Taylor et al. 2016).

8 Conclusions and Recommendations

8.1 Conclusions

Among this population of infantry Soldiers, high cumulative amounts of physical activity were the predominant risk factors for the occurrence of a road marching injury. Both the distance marched and the weight carried are significant contributing factors to injury risk during road marching. Participation in other weight-bearing activities like occupational lifting and resistance training was significantly associated with injury during road marching, indicating that overtraining was potentially occurring.

8.2 Recommendations

Physical training programs should incorporate a variety of activities that are balanced in terms of frequency, duration, and intensity in order to enhance physical endurance and minimize injury risk. Furthermore, those who participated in more road marching were more likely to be injured if the carried load was heavier than 25 percent of their body weight. The weight of carried loads should be reduced to this level and carried as efficiently as possible. As heavy loads are often required during deployment, preventing cumulative overloading from both physical training and occupational tasks may be the most practical approach to reduce road marching-related injuries. While the present study was restricted to Soldiers only, future research may be applicable to other occupations where load carriage is required, such as protective services like firefighters and police officers (Orr et al., 2014).

9 Point of Contact

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Appendix A
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